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A Snow Index

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U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

ESSA TECHNICAL MEMORANDUM

WEATHER BUREAU

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Weather Bureau Technical Memorandum NMC-40

A SNOW INDEX

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NATIONAL METEOROLOGICAL CENTER

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PREFACE

Information contained herein should be of primary interest to the short-range forecaster dealing with the snow versus rain problem. Also, those experimenting with obtaining snow forecasts from numerical prediction precipitation models may find it informative as to lower tropospheric thermal structure during important snowfall.

The substance of this Technical Memorandum is taken from an unpublished report written in 1957 by R. J. Younkin entitled, "1000-850-mb and 850-700-mb Thickness-Precipitation Type Relations".

I. Introduction:

The determination of type of precipitation (liquid or frozen) at temperatures near freezing remains one of the most difficult of forecast problems. Different investigators have found that thickness relations provide one of the best forecast tools for practical application to this problem. Wagner's [1] values of 1000-500-mb thickness for 50% probability of occurrence of frozen precipitation are well-known. Heavy snow is most likely when this layer thickness is between 5410 and 5300 gpm. Precipitation is likely to be in the form of snow showers with 1000-500-mb thickness less than 5250 gpm, and not heavy except for orographic or lake causes.

The intensity of snowfall is, of course, directly associated with the available moisture entering into the precipitation process. The precipitable water in a saturated pseudo-adiabatic atmosphere decreases by one-quarter in the 1000-700-mb layer as the thickness lowers from 2870 to 2820 gpm. The 2870 gpm thickness value is approximately the highest (Eastern United States) at which snow occurs, while heavy and rapidly accumulating snowfall is unlikely with 1000-700-mb thickness less than 2820 gpm. Rapidly accumulating snowfall of two or more inches an hour is most likely to occur in the 2830 to 2855 gpm thickness interval. In general, rain or snow may occur with 1000-700-mb thickness ranging from 2810 to 2870 gpm with 50% probability of frozen precipitation at approximately 2840 gpm.

II. Theory:

The occurrence of precipitation in liquid or solid form (rain, sleet or snow) is determined mainly by the temperature distribution in the lower troposphere. Additional information supplied by thickness values of the 1000-850-mb and 850-700-mb layers allows considerable refinement to location of frozen precipitation areas after first approximations are made from 1000-500-mb or 1000-700-mb thicknesses.

There are three possible combinations of lower tropospheric temperature distribution when forecasters deal with the question as to frozen or liquid precipitation. They are:

A. Below freezing temperature prevails in the upper portion of the lower tropospheric layer, and the lower portion is sufficiently cool for snow to reach the ground.

B. Above freezing temperature occurs in the upper portion of the layer while it is below freezing in the lower portion. Snow melts as it falls through the upper portion and freezes into sleet or freezing rain near or on the ground.

C. Below or near freezing temperature occurs in the upper portion of the layer, and the lower portion is sufficiently warm so that snow falling into the warmer air melts and reaches the ground as rain.

In actual practice, the effective division of the lower tropospheric temperature sounding into an upper and lower portion as to their respective contribution toward melting or freezing would be different in each individual situation. However, since geopotential height data is available for all sounding stations for the 1000, 850 and 700-mb constant pressure surfaces, it is convenient to ascribe the 1000-850-mb thickness as the lower portion of the tropospheric layer in which we are interested and the 850-700-mb thickness as the upper portion. This division allows objective numerical treatment of these layers for thickness combinations which determine type of precipitation.

III. Rain vs. Snow Observations:

Observed thickness values were noted (1954-56) while on routine forecasting duty at Knoxville, Tennessee for selected situations and locations to determine extreme values of 1000-850-mb and 850-700-mb thickness for occurrence of liquid and frozen precipitation. It must be emphasized that these selections were spot-cases at radiosonde stations or interpolated values for locations between stations. All cases were east of the 90th meridian of longitude. In each instance precipitation was intermittent to continuous with precipitation rate of at least 0.20 of an inch in six hours. In organizing the observed limiting 1000-850 and 850-700-mb thickness values for snow occurrences, and by adjusting these observed values by not more than 3 gpm, it was found that cases with surface wet-bulb temperatures less than 36°F. could be arranged in ordered pairs. This ordered-pair arrangement of the two sets of thickness values was such that,

$Y + 2X = 4179$ (fig. 1), where Y and X are respectively the 850-700-mb and 1000-850-mb thickness values in gpm.

Summary statements of types of precipitation occurring with observed extreme thickness values (slightly adjusted) are as follows:

A. Important snow occurs with 850-700-mb thickness as high as 1557 gpm and associated 1000-850-mb thickness as high as 1311 gpm.

B. Also, important snow occurs with 1000-850-mb thickness as warm as 1326 gpm and associated 850-700-mb thickness as warm as 1527 gpm.

C. Rain, freezing rain and sleet (no snow) occurs when the 850-700-mb thickness is greater than 1557 gpm.

D. Freezing rain or sleet occurs when 1000-850-mb thickness is less than 1311 gpm simultaneous with 850-700-mb thickness greater than 1557 gpm.

E. Rain occurs if 1000-850-mb thickness is greater than 1326 gpm.

IV. Surface Wet-Bulb Temperature:

Evaporational cooling often plays an important part in snow reaching the ground. Snow will reach the ground in a short time with surface wet-bulb temperatures at 35°F. and below, provided the precipitation rate is of sufficient intensity and the lower tropospheric temperature distribution is in appropriate accordance with the equation, $Y + 2X = 4179$. However, heavy wet snow can reach the ground with surface wet-bulb temperature above 35°F., sometimes considerably above. A gross adjustment to the equation can be made for these conditions by subtracting 6 gpm from 4179 for each 1°F. of surface wet-bulb over 35°F.

V. 1966-67 Rain vs. Snow Observations:

During the 1966-67 winter season, there were 29 precipitation occurrences selected as marginal as to snow, rain, sleet or freezing rain, and at the same time, simultaneous with radiosonde observations at these locations. All cases were as of 0000 or 1200 GMT for raob stations east of the 90th meridian of longitude. In each case the precipitation amount exceeded 0.20 of an inch during the six hours preceding the synoptic observation. These data (fig. 1) fit reasonably well the earlier linear regression estimates obtained from a limited number of extreme-value instances. These new data indicate a slightly greater slope in the regression line than that given by $Y + 2X = 4179$. However, the simple equation form with slope of - 2 will be used in the subsequent development of a "snow index" to minimize computational intricacy. Also, these new data point to approximately the 1553 gpm 850-700-mb thickness as a more representative boundary between most probable occurrences of snow and sleet or freezing rain, rather than 1557 gpm - the maximum 850-700-mb thickness value for occurrence of snow.

VI. A Snow Index:

A snow index may be obtained from $Y + 2X = 4179$ by adding the 850-700-mb thickness to twice the 1000-850-mb thickness and subtracting this from 4179. Then, positive numbers are indicative of snow. Negative numbers are indicative of rain, sleet or freezing rain, and specifically rain, if the 850-700-mb thickness is greater than 1557 gpm.

This Snow Index could be of considerable value in alerting forecast offices with short-range forecasting responsibilities to a lower tropospheric temperature distribution favorable for snow. It may be computed rapidly and directly from transmitted height values.

Let, A = 1000-mb height (gpm)
B = 850-mb height (gpm)
C = 700-mb height (gpm)

Then, Snow Index = $4179 + 2A - B - C$

Noting that C may be either above or below 3000 gpm in snow situations, using C' for the number of gpm over 3000, C'' for the number of gpm under 3000, and also using B' for the number of gpm the 850-mb height is over 1000, then for quick computation

$$\text{SNOW INDEX} = 179 + 2A - B' - C'$$

$$\text{SNOW INDEX} = 179 + 2A - B' + C''$$

VII. Remarks Pertinent to use of the Snow Index:

A. The Snow Index is most applicable to that area of the United States east of 90° longitude.

B. The Snow Index is designed for moderate to heavy rates of snowfall. It may be positive and fine rain fall for hours. The Index does not necessarily apply to instability showers.

C. Subtract 6 gpm from the Index for each 1°F. the surface wet-bulb temperature is above 35°F.

D. Precipitation type will be sleet or freezing rain with positive Index and while 850-700 thickness is greater than 1557 gpm.

E. A cooling of 1°C. in the 1000-850-mb thickness will increase the Snow Index by approximately 10 gpm.

F. A cooling of 1°C. in the 850-700-mb thickness will increase the Snow Index by approximately 6 gpm.

G. Divide the Snow Index by 16 and the quotient is the mean virtual temperature departure (approximately) in °C. from the warmest 1000-700-mb mean virtual temperature at which important snow can occur, considering the combined thermal distributions in two layers.

H. Examples:

A 1000-mb height - 100 gpm

B 850-mb height - 1406 gpm ($B' = 1406 - 1000$)

C 700-mb height - 2928 gpm ($C'' = 3000 - 2928$)

Surface wet-bulb - 34°F.

$\text{Index} = 179 + 2A - B' + C'' = 179 + 200 - 406 + 72 = +45$

A 1000-mb height - 140 gpm

B 850-mb height - 1450 gpm (B' = 1450 - 1000)

C 700-mb height - 3005 gpm (C' = 3005 - 3000)

Surface wet-bulb - 32°F.

Index = 179 + 2A - B' - C' = 179 + 280 - 450 - 5 = +4

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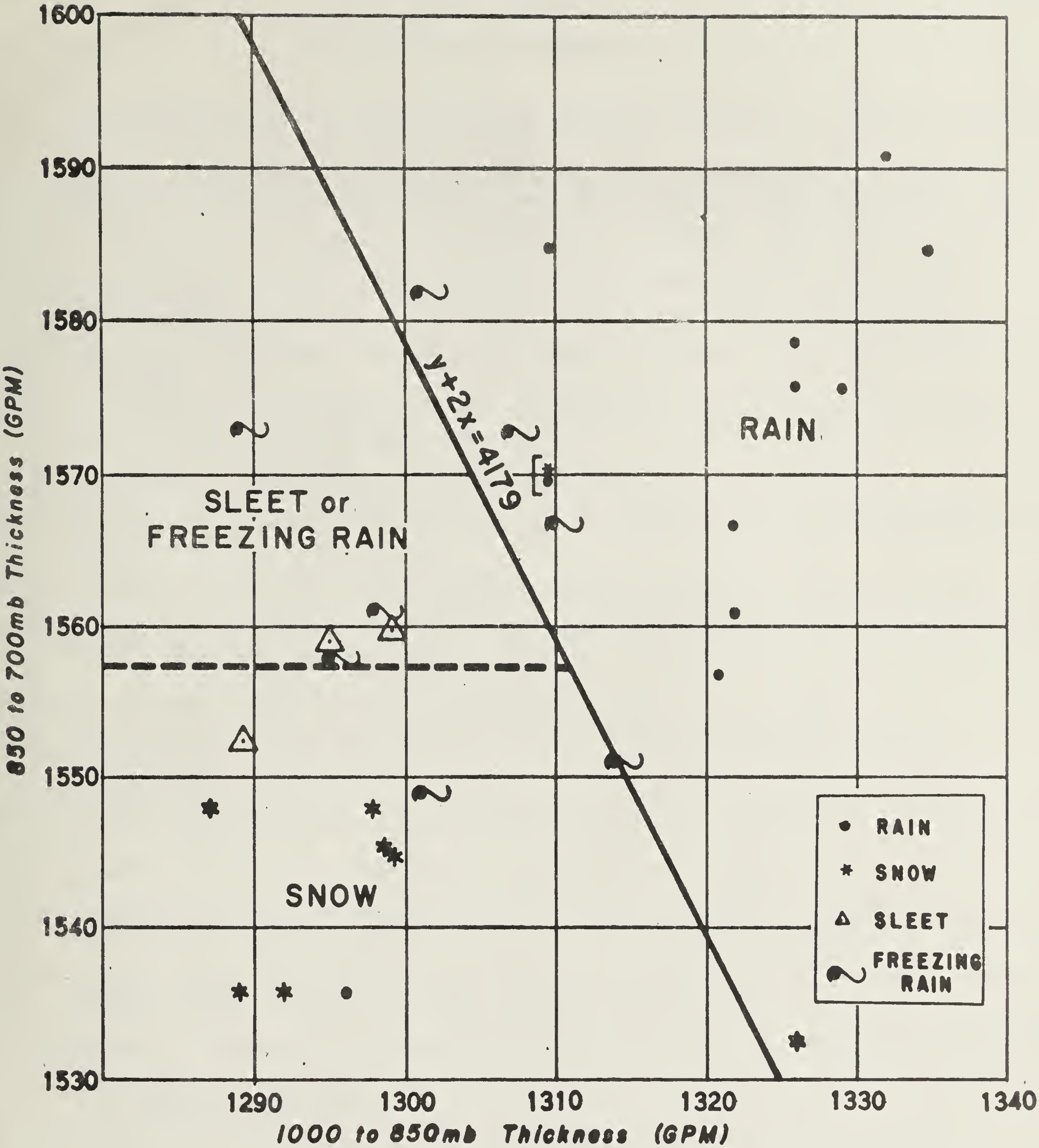

Figure 1. Frozen versus liquid precipitation as related to 1000 to 850-mb and 850 to 700-mb thicknesses for significant precipitation rates and surface wet-bulb temperatures less than 36°F. (1966-67 observed data as compared to linear regression estimate obtained from extreme value situations.)

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